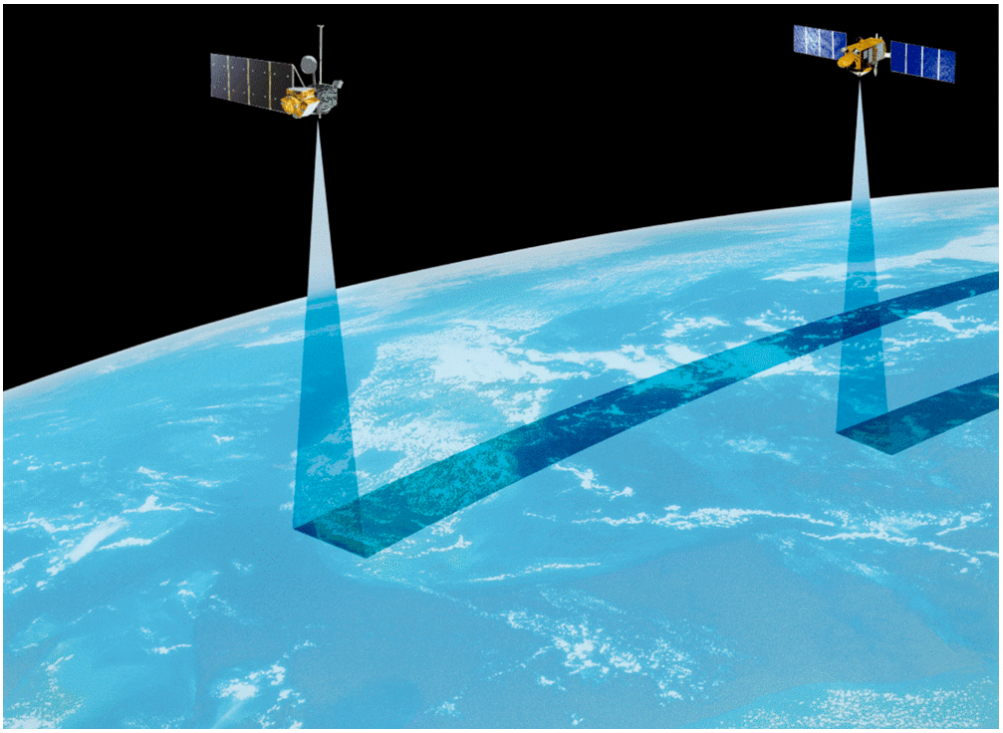
A Satellite Data Primer

Initially prepared for the NOAA ocean satellite data course at OSU/CIOSS, Aug 22-24, 2006 to provide a ***very simplified*** summary of the available satellite data for oceanic uses. The weather and/or atmospheric applications of different satellites are not covered here. For more complete information see the Martin textbook "An introduction to Ocean Remote Sensing", or the powerpoint presentations given during the course.



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Data Websites

The NOAA Ocean Satellite Courses focus on accessing data through the following websites, or using OpenDap delivery protocol to access datasets served on these websites. We strive to offer "one-stop shopping" on these websites, with multiple satellite datasets available, in a range of different formats. Most of the datasets mentioned in this document are served on our browsers. Dataset documentation is available via the "Data Set Info" links on the Coastwatch browsers. Other websites serving satellite datasets are also mentioned in this document on the pages devoted to individual types of data.

Satellite Data Browsers

Alaska:
http://coastwatch.pfel.noaa.gov/coastwatch/CWBrowserAK.jsp

West Coast of the U.S. & Mexico:
http://coastwatch.pfel.noaa.gov/coastwatch/CWBrowser.jsp

Global, (longitude 0° to 360°):
http://coastwatch.pfel.noaa.gov/coastwatch/CWBrowserWW360.jsp

Global, (longitude -180° to 180°):
http://coastwatch.pfel.noaa.gov/coastwatch/CWBrowserWW180.jsp

The EDC, for ArcGIS or the stand-alone module

http://www.pfeg.noaa.gov/products/EDC/ or

http://www.asascience.com/software/downloads/

Xtract-o-matic routines for Matlab & R

http://coastwatch.pfel.noaa.gov/xtracto/

ERD THREDDS server

http://oceanwatch.pfeg.noaa.gov/thredds/catalog.html

ERDDAP

http://coastwatch.pfeg.noaa.gov/erddap
http://coastwatch.pfeg.noaa.gov/erddap/griddap

Orbital Configurations

Satellites orbit the earth in either polar or geostationary orbit (Fig. 1). Those in polar orbit continually circle over the poles and achieve global coverage in roughly a week. Satellites in geostationary orbit stay in a fixed position relative to the earth. Geostationary satellites have a much higher sampling frequency for a particular area than polar orbiting satellites, allowing better sampling of cloudy areas. However geostationary satellites can't get global coverage, and they do not sample high latitudes regions very well because of the oblique angle between the earth's surface and the satellite sensor. Because of the high orbit of geostationary data it's more challenging to obtain the high spatial resolution of data from polar orbiting satellites. Most environmental satellite data comes from satellites in polar orbit, however geostationary SST data is available, and Korea launched an ocean color sensor (GOCI) on a geostationary satellite in June 2010.

Fig. 1. Examples of sun-synchronous (polar-orbiting), geosynchronous and low-inclination orbits. Geosynchronous (also called geostationary) satellites orbit at ~36,000 km, while polar-orbiting satellites are at ~800 km altitude. Figure from Martin textbook "An Introduction to Ocean Remote Sensing" (Fig. 1.3).

Sea-Surface Temperature (SST)

Brief Description: SST measurements can be made from both IR and passive microwave, and from both polar-orbiting and geostationary orbit. The highest spatial resolution (~ 1 km) datasets are from polar-orbiting IR measurements using the AVHRR.

Caveats: SST from IR measurements can not measure through clouds. SST data from passive microwave measurements can see through clouds but have a lower spatial resolution than IR measurements. Passive microwave SST measurements are not possible within a ~75 km band next to land, or in times of heavy rainfall. Geostationary measurements of SST can alleviate cloud coverage problems because of their frequent sampling. Geostationary measurements do not sample high latitudes regions very well because of the oblique angle between the earth's surface and the satellite sensor.

Current Platforms/Datasets

AVHRR Pathfinder dataset has science-quality data from 1985 onward from the AVHRRs on NOAA's polar orbiting satellites. The latest version (version 5) has a spatial resolution of 4 km, an improvement from the previous version which was 9 km.

MODIS SST from Terra (10/00 onward) and Aqua (12/02 onward) is available at 4km and 9km resolution

GOES (geostationary) SST data is available from 5/03 onward at a resolution of 6 km for the region between 45°S-60°N and 180°-30°W

TMI on **TRMM** provides microwave SST between 40°S-40°N, at ~25 km spatial resolution from 12/97 onward.

AMSR-E on **Aqua** provides microwave SST between 40°S-40°N, at 38 km and 56 km spatial resolution from 12/02 onward.

Derived or related products

Frontal products are derived from SST by measuring the spatial temperature gradient.

There are blended products available that have been produced to minimize data loss through cloud coverage.

Additional websites with data or further information

Pathfinder 4km website:
http://www.nodc.noaa.gov/sog/pathfinder4km

JPL's PO DAAC (Physical Oceanography Distributed Active Archive Center):
http://podaac.jpl.nasa.gov/sst

POET, JPL's PO.DAAC Ocean ESIP Tool (POET) for plotting and subsetting data
http://poet.jpl.nasa.gov

Remote Sensing Systems, specializes in microwave satellite measurements
http://www.ssmi.com

Group for High Resolution SST (GHRSST)
http://www.ghrsst-pp.org

Sea-Surface Height (SSH)

Brief Description: Altimeters use active radar to measure the surface elevation of the ocean, relative to a reference level (the mean geoid). Satellite SSH data provides information about the ocean circulation, integrated surface height content, eddy movement, geostrophic currents and changes in global sea level. Measurements of SSH are not affected by cloud coverage. They can not be retrieved within ~15 km of land.

Past and Current Platforms

GEOSAT	3/85-1/90
TOPEX/Poseidon	8/92-10/05
JASON-1	12/01 onward
JASON-2	6/08 onward
ERS-1	7/91-6/95
ERS-2	4/95 onward
Envisat	3/02 onward
Cryosat-2	4/10 onward

Planned Future Platforms

Cryosat-2	2010
HY-2A	2011
JASON-3	2013
Sentinel-3A	2013

Derived or related products

Geostrophic currents can be derived from the slope of SSH.

Additional websites with data or further information

JPL's Ocean Surface Topography from Space page
http://sealevel.jpl.nasa.gov

JPL's PO DAAC (Physical Oceanography Distributed Active Archive Center):
http://podaac-www.jpl.nasa.gov/ost

POET, JPL's PO.DAAC Ocean ESIP Tool (POET) for plotting and subsetting data
http://poet.jpl.nasa.gov

AVISO (France)
http://www.aviso.oceanobs.com

NOAA's OSCAR (Ocean Surface Current Analyses – Real time) site
http://www.oscar.noaa.gov

Ocean Color (Chlorophyll)

Brief Description: Chlorophyll-a concentration is calculated from the normalized water-leaving radiances at several different visible wavelengths. The number of wavelengths varies between different sensors (CZCS had 5, SeaWiFS 8, and MODIS 9). The algorithm is optimized for open-ocean (case-I) water, and the presence of sediments and colored dissolved organic material (CDOM) can affect the accuracy of the measurements in coastal (case-II) waters. Cloud coverage can be a significant issue in some areas.

Past and Current Platforms

CZCS:	11/78-6/86 (incomplete global coverage)
SeaWiFS:	9/97-2/11 (intermittent power problems starting in 1/08)
MODIS/Terra:	2/00 onward (calibration problems with chlorophyll)
MODIS/Aqua:	6/02 onward
MERIS	3/02 onward
OCM-2 (India)	9/09 onward (uncertainties about both data calibration and access)
GOCI (Korea)	launched 6/10

Planned Future Platforms

VIIRS on NPP	2011
OLCI (Europe)	2013
S-GLI (Japan)	2014
VIIRS on JPSS-1	2016
VIIRS on JPSS-2	2019

Derived or related products

Primary productivity can be derived from chlorophyll using PAR, SST and day length. The most widely-used algorithm is that of Behrenfeld and Falkowski, 1997. (Limnol. Oceanogr., 42, 1479-1491).

PAR (Photosynthetically available radiation) measurements from SeaWiFS provide the amount of incoming radiation from the sun between 400-700 nm.

Fluorescence Line Height from MODIS instruments on Aqua and Terra provides information on the phytoplankton health.

K490 is diffuse attenuation coefficient data at 490 nm wavelength available from the MODIS instruments on Aqua and Terra and from SeaWiFS. It is a good measure of water clarity.

Additional websites with data or further information

NASA's OceanColor Web
http://oceancolor.gsfc.nasa.gov/

NASA's Ocean Color Time-Series Online Visualization and Analysis System
http://reason.gsfc.nasa.gov/Giovanni/
International Ocean-Colour Coordinating Group
http://www.ioccg.org/

Surface Vector Winds (SVW)

Brief Description: A scatterometer is a high frequency microwave radar designed specifically to measure ocean near-surface wind speed and direction.

Past and Current Platforms

NSCAT on ADEOS	9/96-6/97
SeaWinds on QuikScat	7/99-11/09
SeaWinds on ADEOS-II	4/02-10/03
ASCAT on METOP-A	10/06 onward
Scatterometer on Oceansat-2	9/09 onward

Planned Future Platforms

Scatterometer on HY-2A	2011
ASCAT on METOP-B	2012
Scatterometer on CFOSat	2013

Derived or related products

Wind stress is derived from wind speed and direction and provides an indication of the amount of work done by the wind to the ocean
Wind stress curl provides a measure of the pattern of the wind field. Areas of strong curl cause divergence in the surface layer and result in upwelling
Ekman upwelling is a measure of the vertical movement of water as a result of wind-driven horizontal water movement at the ocean surface

Additional websites with data or further information

JPL's Winds Page
http://winds.jpl.nasa.gov

JPL's PO DAAC (Physical Oceanography Distributed Active Archive Center):
http://podaac-www.jpl.nasa.gov/ovw

POET, JPL's PO.DAAC Ocean ESIP Tool (POET) for plotting and subsetting data
http://poet.jpl.nasa.gov

Remote Sensing Systems, specializes in microwave satellite measurements
http://www.ssmi.com

Sea Ice

Brief Description: Passive microwave instruments such as ESMR, SMMR and SSM/I, and radar such as ERS-1, ERS-2, and RADARSAT provide the main data sets used for sea ice studies because of their nighttime and all-weather capabilities.

Passive microwave data provides measurements of the ice edge, sea ice concentrations, and classification of different types of sea ice types. Passive microwave imagery is available from late 1978 through the present. Earlier but less reliable data from the ESMR are available from late 1972 to 1976.

Past and Current Platforms

ESMR	12/72-12/76
SMMR	10/78-8/87
SSM/I	6/87-9/09
AMSR-E on Aqua	4/02 onward
GLAS on ICESat	1/03-10/09
Cryosat-2	04/10 onward

Planned Future Platforms

ICESat-2	2015

Additional websites with data or further information

Alaska CoastWatch browser
http://coastwatch.pfeg.noaa.gov/coastwatch/CWBrowserAK.jsp

National Snow and Ice Data Center
http://nsidc.org

High Resolution Sensors

Brief Description: There are a number of sensors with high spatial resolution, meaning <100 m. The trade-off on such a high resolution is temporal resolution, and these sensors generally have very long repeat-times, and some don't have regular repeat times, but rather work on a system of scheduled, on-demand acquisitions. These data are generally better suited for land applications than for ocean applications. The datasets are generally harder to get ahold of, and most of the scenes have to be bought. However some of these data will be discussed in the 2010 satellite courses, as they have been used extensively to monitor the BP oil spill in the Gulf of Mexico, and subsequentially some of the data have become more available to the general public.

Sensor	Launch	Failure	Resolution*	Swath	Repeat
ALI	11/00		10 m, 30 m	8 km	16 d
ALOS	1/06		2.5 m, 10 m	35-70 km	46 d
ASTER	12/99		15 m, 30 m	60 km	16 d
FORMOSAT-2	5/04		2 m, 8 m	24 km	1 d
GeoEye-1	8/01		0.4 m, 1.6 m	15 km	
Hyperion	11/00		30 m	8 km	16 d
IKONOS	9/99		1 m, 4 m	13-70 km	14 d
KOMPSAT-1	12/99		6 m	24 km	28 d
KOMPSAT-2	7/06		1 m, 4 m	15 km	14 d
Landsat-5, TM	3/84		30 m	185 km	16 d
Landsat-7, ETM+	4/99		15, 30 m	185 km	16 d
OrbView-3	6/03		1 m, 4 m	8 km	3 d
SPOT-1	2/86	12/90	10 m, 20 m	60 km	
SPOT-2	1/90	7/09	10 m, 20 m	60 km	
SPOT-3	9/93	11/97	10 m, 20 m	60 km	
SPOT-4	4/98		20 m	60 km	26 d
SPOT-5	5/02		2.5-5 m, 10 m	60 km	2-3 d
QuickBird	10/01		0.6 m, 2.4 m	16 km	2-3 d

*resolutions listed are panchromatic (BW) and multispectral.

Glossary of Names & Acronyms

Satellite data products are usually referred to by their sensor name, when the same instrumentation is on different satellites, they are distinguished by the name of the satellite, which can be part of a larger program of satellites. For example a MODIS sensor is on both the Terra and Aqua satellites, satellites which are part of NASA's EOS program. There is also a longer list of acronyms in the front of the Martin textbook and there is also a good list at http://www.noc.soton.ac.uk/lso/acronyms.php that has sensors, satellites and agencies listed separately.

ADEOS	**AD**vanced **E**arth **O**bserving **S**atellite, ADEOS-1 flew 8/96-6/97, ADEOS-2 was launched in 12/02 but lost power 10/03 (Japan)
ALI	**A**dvanced **L**and Imager on EO-1 (NASA)
ALOS	**A**dvanced **L**and **O**bserving **S**atellite, launched 1/06 (Japan)
AMSR	**A**dvanced **M**icrowave **S**canning **R**adiometer on ADEOS-2 (Japan)
AMSR-E	**A**dvanced **M**icrowave **S**canning **R**adiometer-**E**OS (Japan) on Aqua
AOPs	**A**pparent **O**ptical **P**roperties
Aqua	NASA satellite flying multiple sensors, including the MODIS sensor. Launched 4/02. Part of EOS.
Aquarius	Sea-surface salinity satellite to be launched 2012 by NASA
ASCAT	**A**dvanced **Scat**terometer on MetOp-A launched in 10/06 by ESA
ASTER	**A**dvanced **S**paceborne **T**hermal **E**mission and **R**eflection **R**adiometer on Terra
AVHRR	**A**dvanced **V**ery **H**igh **R**esolution **R**adiometer measures SST. The first AVHRR instrument was launched by NOAA in 1978.
AVISO	**A**rchiving, **V**alidation and **I**nterpretation of **S**atellite Oceanographic data (France)
CFOSAT	**C**hinese-**F**rench **O**ceanic **SAT**ellite, planned launch 2013 for SVW
CryoSat	**Cryo**sphere **Sat**ellite. Destroyed on launch, 10/05 (ESA)
CryoSat-2	2nd **Cryo**sphere **Sat**ellite. Launched 4/10 (ESA)
CNES	**C**entre **N**ational d'**E**tudes **S**patiales (France)
CZCS	**C**oastal **Z**one **C**olor **S**canner (NASA, 78-86)
EDC	**E**nvironmental **D**ata **C**onnector. A plug-in for ArcGIS developed to facilitate importing satellite data into ArcGIS.
ESMR	**E**lectrically **S**canning **M**icrowave **R**adiometer, flew 12/72-12/76
EMR	**E**lectro**M**agnetic **R**adiation
EnviSat	**Envi**ronmental **Sat**ellite, follow-on to ERS-1 and ERS-2 (ESA)
EO-1	**E**arth **O**bserving-1, the 1st satellite in NASA's EOS Program, launched 11/00
EOS	**E**arth **O**bserving **S**ystem mission including a series of satellites (NASA)
EPS	**E**UMETSAT **P**olar **S**ystem
ERS	**E**uropean **R**emote-sensing **S**atellite. ERS-1 7/91-6/95, ERS-2 launched 4/95

ESA	**E**uropean **S**pace **A**gency
ETM+	**E**nhanced **T**hematic **M**apper Plus, on Landsat-7
EUMETSAT	**Eu**ropean Organization for the Exploitation of **Met**eorological **Sat**ellites
FORMOSAT	high resolution satellite developed by Taiwan
GAC	**G**lobal **A**rea **C**overage
GCOM	**G**lobal **C**hange **O**bservation **M**ission, ADEOS-II follow on (Japan)
GCOM-C	**G**lobal **C**hange **O**bservation **M**ission-**C**arbon, 2014 launch (Japan)
GCOM-W	**G**lobal **C**hange **O**bservation **M**ission-**W**ater, 2011 launch (Japan)
GeoEye-1	a commercial high-resolution imagery satellite
GHRSST	**G**roup for **H**igh **R**esolution **SST**
GLI	**Gl**obal **I**mager on ADEOS-2 (Japan, 12/02-10/03)
GOCI	**G**eostationary **O**cean **C**olor **I**mager (Korea) 6/10 launch
GOES	**G**eostationary **O**perational **E**nvironmental **S**atellites (NOAA). Named by letters pre-launch, and numbers post-launch. Collect primarily weather data, but geostationary SST available from 5/03 onward.
GSFC	**G**oddard **S**pace **F**light **C**enter. A NASA laboratory.
HRPT	**H**igh **R**esolution **P**icture **T**ransmission ground stations for satellite reception
HY-2A	**H**ai**Y**ang ('ocean' in Chinese). Chinese satellite to be launched in 2011.
Hyperion	high resolution hyperspectral imaging instrument on EO-1 (NASA)
IceSat	**I**ce, **C**loud, and Land **E**levation Satellite, launched 1/03 (NASA)
IFOV	**I**nstantaneous **F**ield **O**f **V**iew, determines a satellite's pixel size
IKONOS	a commercial high-resolution imagery satellite, name derived from the Greek term *eikōn* for image
IOCCG	**I**nternational **O**cean-**C**olour **C**oordinating **G**roup
IOPs	**I**nherent **O**ptical **P**roperties
IPO	**I**ntegrated **P**roject **O**ffice, set up to administer NPOESS (US)
IR	**I**nfra**r**ed wavelengths
ISRO	**I**ndian **S**pace **R**esearch **O**rganisation
JASON-1	Follow-on to the TOPEX/Poseidon altimeter. Launched 12/01.
JASON-2	Follow-on to the TOPEX/Poseidon and Jason-1 satellites. Launched 6/08.
JAXA	**J**apan **A**erospace **E**xploration **A**gency
JPSS	**J**oint **P**olar **S**atellite **S**ystem. A joint NOAA and NASA project, created in Feb 2010 to replace NPOESS
K490	Diffuse attenuation coefficient data at 490 nm wavelength
K-band	Frequencies between 11 and 36 GHz
K_u-band	Frequencies ~14 GHz
KOMPSAT	**KO**rean **M**ulti**P**urpose **SAT**ellite (commercial, high resolution)

GLAS	**G**eoscience **L**aser **A**ltimeter **S**ystem on ICESat (NASA, 1/03-10/09)
GLI	**Gl**obal **I**mager on ADEOS-2 (Japan, 8/96-6/97)
LAC	**L**ocal **A**rea **C**overage
Landsat	A US satellite program established in 1972 to ensure satellite observations of the Earth's land surfaces. LandSat-7 was launched in 5/99
L-band	Frequencies of about 1 GHz
MERIS	**Me**dium **R**esolution **I**maging **S**pectroradiometer (ESA, launched 3/02)
MetOp	**Met**eorological **Op**erational satellite programme (EUMETSAT)
MetOp-A	the first of three satellites in this program, launched 10/06, declared operational 5/07
MetOp-B	launched planned for 2012
MetOp-C	launched planned for 2016
MLAC	**M**erged **L**ocal **A**rea **C**overage
MODIS	**Mod**erate Resolution **I**maging **S**pectroradiometer (NASA) measures chlorophyll and SST, instruments on two different satellites: Aqua and Terra. Chlorophyll from MODIS/Terra has calibration issues.
nadir	Point on the ground directly in line with the satellite and the center of the Earth
NESDIS	**N**ational **E**nvironmental **S**atellite, **D**ata and **I**nformation **S**ervice (NOAA)
NIR	**N**ear **I**nfra**r**ed, ~0.7-1.4 micrometers
NMFS	**N**ational **M**arine **F**isheries **S**ervice (NOAA)
NPOESS	**N**ational **P**olar-orbiting **O**perational **E**nvironmental **S**atellite **S**ystem (a NOAA, NASA, and DOD project, which was dismantled in Feb 2010 and replaced by JPSS)
NPP	**N**POESS **P**reparatory **P**roject (not renamed despite NPOESS being renamed)
OceanSat-1	**Ocean**ographic **Sat**ellite flying the OCM (India, launched 5/99)
OceanSat-2	**Ocean**ographic **Sat**ellite flying the OCM (India, launched 9/09)
OCTS	**O**cean **C**olor and **T**emperature **S**canner on ADEOS-1 (Japan, 8/96-6/97)
OCM	**O**cean **C**olor **M**onitor on OceanSat-1 (India, launched 5/99)
OCM-2	**O**cean **C**olor **M**onitor-2 on OceanSat- 2 (India, launched 9/09)
OLCI	**O**cean **L**and **C**olour **I**nstrument (ESA, launch planned for 2013)
OPeNDAP	**O**pen-source **P**roject for a **N**etwork **D**ata **A**ccess **P**rotocol. A data transport architecture and protocol which allows efficient methods to serve large collections of data
OrbView-3	a commercial high-resolution imagery satellite
OSCAR	**O**cean **S**urface **C**urrent **A**nalyses – **R**eal time (NOAA)
OSTM	**O**cean **S**urface **T**opography **M**ission on Jason-2 (joint NOAA/NASA/CNES/EUMETSAT project, launched 7/08)
PAR	**P**hotosynthetically **A**vailable **R**adiation

Pathfinder	Science-quality 4-km resolution SST product going back to 1985
POES	**P**olar **O**perational **E**nvironmental **S**atellites (NOAA)
QuickBird	a commercial high-resolution imagery satellite
QuikScat	satellite flying the first SeaWinds scatterometer, launched 6/99 (NASA)
R2O	**R**esearch to **O**perations.
SAR	**S**ynthetic **A**perature **R**adar
SeaWiFS	**Sea**-viewing **Wi**de **F**ield-of-view **S**ensor, measures ocean chlorophyll. Launched in Aug 1997 by NASA, but commercially owned by GeoEye (formerly OrbImage). Died 2/14/2011.
SeaWinds	scatterometer on QuikScat and ADEOS-2 satellites
Sentinel-3	a future ESA mission from ESA, with an altimeter and the OLCI, planned for 2013 launch.
S-GLI	**S**econd-Generation **G**lobal **I**mager to be flown on GCOM-C (Japan, launch date in 2014)
SSH	**S**ea-**S**urface **H**eight
SPOT	**S**atellite **P**our l'**O**bservation de la **T**erre. Five have been launched since 1986 (France, commercial)
SMMR	**S**canning **M**ultichannel **M**icrowave Radiometer, 10/78-8/87
SSM/I	**S**pecial **S**ensor **M**icrowave/**I**mager
SST	**S**ea-**S**urface **T**emperature
SWIR	**S**hort-**w**avelength **I**nfra**r**ed, ~1.4-3 micrometers
SVW	**S**urface **V**ector **W**inds
Terra	NASA satellite flying a MODIS sensor. Launched 12/99. Part of EOS.
ThREDDS	**Th**ematic Realtime **E**nvironmental **D**istributed **D**ata **S**ervices. This project is developing middleware to bridge the gap between data providers and data users.
TIR	**T**hermal **I**nfra**r**ed, ~3.5-20 micrometers
TM	**T**hematic **M**apper, on Landsat-5
TMI	**T**RMM **M**icrowave **I**mager, microwave SST sensor on TRMM satellite
TOA	**T**op **o**f **A**tmosphere
T/P	**T**OPEX/**P**oseidon, altimeter for SSH, 8/92-10/05 (NASA, France)
TRMM	**T**ropical **R**ainfall **M**easuring **M**ission satellite (NASA), launched 11/97
VIIRS	**V**isible **I**nfrared **I**mager/**R**adiometer **S**uite to be flown on NPP and JPSS to measure ocean color and SST
X-band	Frequencies of about 10 GHz